Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

84 D
no. 959

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 959

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER October 8, 1921

U. S. F. S. RECEIVED
LIBRARY
OCT - 1921

EXPERIMENTS AND SUGGESTIONS FOR THE CONTROL OF THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO.[1]

By E. H. SIEGLER, *Entomologist*, and H. K. PLANK,[2] *Scientific Assistant, Fruit Insect Investigations, in cooperation with the Colorado Agricultural Experiment Station.*

CONTENTS.

Page.
The Grand Valley of Colorado 2
  Comparison of the climatic conditions of Grand Junction, Colo., and Rochester, N. Y. 2
Spraying experiments in the Grand Valley.. 3
  Spraying experiments in 1915 4
  Spraying experiments in 1916 7
  Spraying experiments in 1917 11
  Spraying experiments in 1918 25
  Summary of results 29
Suggestions for the control of the codling moth in the Grand Valley of Colorado.... 30
  Avoid presence of spray residue on harvested fruit 33
  Spray materials 34
  Spraying equipment 34
Supplemental control measures 35
  Banding 35
  Codling-moth trap 35

Owing to the great abundance and destructiveness of the codling moth (*Laspeyresia pomonella* L.) in the Grand Valley of Colorado, the Bureau of Entomology of the United States Department of Agriculture, in cooperation with the Colorado Agricultural Experiment Station, undertook in 1915 a study of its life history and control. The biological study was concluded the following year, but the control investigations continued during 1916, 1917, and 1918.

In this report are given the more important results of the spraying experiments and some suggestions for the control of the codling moth in the Grand Valley.

---

[1] In 1915 and 1916 the senior author was in immediate charge, assisted by E. R. Van Leeuwen, of the Bureau of Entomology, during the former season and by H. K. Plank, also of the bureau, during the latter. In 1917 Mr. Plank had charge of the project, assisted by Leo. C. Antles, of the Colorado Agricultural Experiment Station, and during the following year Mr. Antles carried out the experiments under the general direction of Mr. Plank and the Colorado Experiment Station.

Dr. A. L. Quaintance, in charge of fruit insect investigations, Bureau of Entomology, and Dr. C. P. Gillette, George M. List, and Claude Wakeland, of the Colorado Agricultural Experiment Station, made many helpful suggestions throughout the course of the work. The writers also wish to express their appreciation for the cooperation of the Grand Valley fruit growers.

[2] Resigned June 30, 1920.

THE GRAND VALLEY OF COLORADO.

The Grand Valley is one of the most important fruit-growing regions of Colorado, having approximately 15,000 acres devoted to such fruits as apples, pears, peaches, plums, cherries, and bush fruits. About 10,000 of these acres are planted to apples and 2,500 to pears, both of which (and particularly the apple) are heavily attacked by the codling moth.

LOCATION AND TOPOGRAPHY.

The Grand Valley is in the western part of Mesa County and extends from Palisades to Fruita, about 32 miles. The valley follows the course of the Grand River and is generally level, except for the sections known as the Fruit Ridges, which are somewhat elevated and rolling. The district of Orchard Mesa, although higher than the rest of the valley, is typical level, or mesa, land. The lower part of the valley is approximately 4,500 feet above sea level and the upper district at Palisades is about 4,800 feet in elevation.

CLIMATE.

The climate is comparatively dry, and the crops are irrigated principally by means of water taken from the Grand River. The annual precipitation is but 8 to 9 inches, and during the five months from May to September, in which season the apple and codling moth are developing, the rainfall amounts to only from 3 to 4 inches. The mean normal temperature during the same period is about 70.6° F.

COMPARISON OF THE CLIMATIC CONDITIONS OF GRAND JUNCTION, COLO., AND ROCHESTER, N. Y.[3]

Since the development and severity of the codling moth are largely influenced by climatic factors, it may be of interest to compare the weather conditions of the Grand Valley with those of the western New York apple belt. Under the semiarid conditions that exist in the Grand Valley, the codling moth causes great injury to the fruit crop and is very difficult to control, whereas under the relatively cooler and more humid conditions of western New York the codling moth is much less troublesome.

In Table 1 will be found data giving a comparison of the mean normal temperature and precipitation of Grand Junction, Colo., and Rochester, N. Y.[4] It will be noted therein that the total normal precipitation in the Grand Valley during the growing season, or from May to September, inclusive, is only about one-fourth as much as in western New York and that the mean temperature is about 6° F. higher than that of Rochester, N. Y.

---

[3] Grand Junction, Colo., is the approximate center of the Grand Valley, and Rochester, N. Y., is in the midst of the western New York apple belt.

[4] Climatological data, U. S. Weather Bureau.

TABLE 1.—*Comparison of mean normal temperature and precipitation, Grand Junction, Colo., and Rochester, N. Y.*

Month.	Grand Junction, Colo.		Rochester, N. Y.	
	Mean normal temperature.	Mean normal precipitation.	Mean normal temperature.	Mean normal precipitation.
	° *F.*	*Inches.*	° *F.*	*Inches.*
May	58.9	0.92	56.7	2.94
June	72.6	0.40	65.9	3.13
July	79.2	0.50	70.4	3.09
August	76.1	1.04	68.3	2.96
September	66.4	0.95	61.9	2.32
Average or total	70.6	3.81	64.4	14.44

In the course of the life-history investigations in the Grand Valley it was found that a female moth deposited as many as 316 eggs and that several laid over 300 eggs each.[5] In other localities where the Bureau of Entomology has conducted similar investigations, the fecundity of the female moth has never been found to be so high. The nearest approach to the individual egg production in the Grand Valley was found in the Pecos Valley of New Mexico, where like climatic conditions obtain and where one female moth was recorded to have produced 259 eggs.[6] In the fruit belt of western Michigan, where the weather conditions approximate those of western New York, the most eggs laid by a moth, according to the records of A. G. Hammar, was 161.[7]

It has been quite generally established that semiarid climatic conditions are very favorable to the development of the codling moth, whereas humid conditions and lower temperatures retard its development.

SPRAYING EXPERIMENTS IN THE GRAND VALLEY.

Spraying experiments were conducted in several orchards during the seasons of 1915, 1916, 1917, and 1918, on representative apple varieties. The results herewith presented, however, are confined to the Ben Davis and Gano, since the Grand Valley fruit growers generally experienced more difficulty in controlling the codling moth on these than on any other commercial varieties.

In the spraying experiments described an attempt was made to time the spray applications according to the development of the codling moth as indicated by the life-history studies and field observations. These studies revealed the fact that there are two full broods of larvæ and a partial third during the growing season in the Grand Valley and that these overlap to a certain extent, some larvæ hatching practically every day. In general, the hatching of each brood of larvæ begins first in small numbers, then in increasing numbers until the maximum is attained, after which there is a gradual decrease until the last larva of the brood has hatched.[8] A tentative spraying schedule, based on certain intervals between applications, was adopted and closely adhered to throughout the work, except when it seemed advisable or became necessary to deviate therefrom.

---

[5] Siegler, E. H., and Plank, H. K. The Life History of the Codling Moth in the Grand Valley of Colorado. U. S. Dept. Agr. Bul. 932. 1921.

[6] Quaintance, A. L., and Geyer, E. W. Life History of the Codling Moth in the Pecos Valley, New Mexico. U. S. Dept. Agr. Bul. 429. 1917.

[7] Hammar, A. G. Life History Studies on the Codling Moth in Michigan. U. S. Dept. Agr. Bur. Ent. Bul. 115, Pt. 1. 1912.

SPRAYING EXPERIMENTS IN 1915.

The growing season of 1915 was extremely abnormal in so far as it related to the crop of apples and abundance of the codling moth. The fruit crop of the valley was practically destroyed just as the petals had dropped by the freezes of May 2, 3, and 4. Temperatures as low as 22° F. were recorded in some sections, killing apples and pears except at Palisades where peaches constitute the chief crop and in a few smudged orchards located elsewhere.

The apple orchard of Mr. Gus J. Johnson, of Highland Park, was among those that were partly saved by the timely use of oil heaters, and was available for experimental purposes. (Pl. I, fig. 1.) This orchard consisted of the Ben Davis, Jonathan, Black Twig, Winesap, and Rome Beauty varieties and was divided into 10 plats, including the unsprayed or check plat.

In Tables 2 and 3 will be found data of the experiments. Two spray poles were used, one of which was operated from the top of the spray tank and the other from the ground. Bordeaux nozzles were used for the calyx treatment except in Plat VI, and nozzles of the eddy-chamber or whirlpool-disk type were employed for all cover sprays in all of the sprayed plats except in plat VI; in this plat Vermorel nozzles were used in all applications. Plats I, II, and IX, located in different sections of the orchard, received identical treatment, a total of four cover sprays, two for the first brood and two for the second and third broods. Plats III and IV were given five cover sprays each, the former receiving three for the first brood and two for the later broods and the latter two for the first and three for the subsequent broods. Plat V was given a total of three cover sprays, two for the first brood and one for the broods that followed. Plat VI was sprayed throughout the season with a very fine mist spray delivered by Vermorel nozzles under a pressure of 90 pounds. Two cover sprays were applied for the first-brood larvæ followed by two more cover sprays for the second and third broods, making four cover treatments in all. Plats VII and VIII were given the same number of applications as plats I, II, VI, and IX, but in plat VII homemade arsenate of lime paste [9] was substituted for arsenate of lead paste, and in plat VIII commercial arsenate of lime powder was used. Plat X was unsprayed for comparison with the treated plats.

---

[8] For further details see U. S. Dept. Agr. Bul. 932, The Life History of the Codling Moth in the Grand Valley of Colorado, by the present authors.

TABLE 2.—*Spraying schedule for the codling moth, Johnson orchard, Grand Valley of Colorado, 1915.*

Number of plat.	Calyx spray.	Cover sprays—first brood.			Cover sprays—second and third broods.		
	A.	B.	C.	D.	E.	F.	G.
	Petals off, May 5-7.	3 to 4 weeks after A, May 24-26.	21 to 22 days after B, June 14-15.	14 days after C, June 28.	10 to 11 weeks after A, July 16-17.	21 to 24 days after E, Aug. 6-9.	22 days after F, Aug. 28.
I	First	Second	Third		Fourth	Fifth	
II	do	do	do		do	do	
III	do	do	do	Fourth	Fifth	Sixth	
IV	do	do	do		Fourth	Fifth	Sixth.
V	do	do	do		do		
VI	do	do	do		do	Fifth	
VII	do	do	do		do	do	
VIII	do	do	do		do	do	
IX	do	do	do		do	do	
X	Check						

TABLE 3.—*Treatment of plats for the codling moth, Johnson orchard, Grand Valley of Colorado, 1915.*

Number of plat.	Spray materials.	Pressure.	Spraying equipment.	
			Calyx spray.	Cover sprays.
		Pounds.		
I	Arsenate of lead, paste, 2 pounds—50	200-225	Bordeaux nozzles.	Whirlpool-disk nozzles.
II	do	200-225	do	Do.
III	do	200-225	do	Do.
IV	do	200-225	do	Do.
V	do	200-225	do	Do.
VI	do	90	Vermorel nozzles	Vermorel nozzles.
VII	Arsenate of lime, homemade, 2 pounds—50.	200-225	Bordeaux nozzles.	Whirlpool-disk nozzles.
VIII	Arsenate of lime, commercial powder, ¾ pound—50.	200-225	do	Do.
IX	Arsenate of lead, paste, 2 pounds—50	200-225	do	Do.
X	Check—unsprayed			

The results of these experiments will be found in Table 4, by reference to which it will be seen that plats I, II, and IX, the treatments of which were alike, produced from 52.88 to 68.41 per cent of fruit free from worms. Under the varying conditions that exist in most orchards, such as unevenness of insect infestation, likelihood of moth migration, differences among the trees in the crop yield, and other contributing factors, uniform results can not always be obtained. Because of these conditions in commercial orchards one section frequently is wormier than another, although the treatment is uniform throughout the orchard. Plat III, in which three cover applications were made for the first brood and two for the later broods, produced the best crop of apples from the point of insect control, 72.22 per cent of the fruit being free from worms. Plat IV was treated with the same number of cover sprays as plat III, but the number of applications for the broods was reversed, and with this treatment 66.48 per cent of the fruit was free from worm infestation. In plat V only three cover sprays were applied, and the treatment resulted in 62.21 per cent of uninfested fruit. As previously noted, plat VI was sprayed five times by means of Vermorel nozzles with a pressure of but 90 pounds, producing a very fine mistlike spray. Generally speaking the results indicate that this treatment was as effective as the other methods employed, there being 63.78 per cent of worm-free fruit. The low-pressure mist spray also gave as good results as the high-pressure coarse sprays in preventing the entrance of larvæ through the calyx end of the apple. It should be borne in mind, however, that in commercial spraying a reasonably high pressure of 200 to 250 pounds will increase the speed of the work and that the distribution of the spray material is likely to be more thorough than when applied under a low pressure.

---

[9] For method of preparation see U. S. Dept. Agr. Bul. 278, Miscellaneous Insecticide Investigations, by E. W. Scott and E. H. Siegler.

Arsenate of lime, both homemade and commercial, as used in plats VII and VIII, gave comparatively poor results.

The unsprayed or check trees, plat X, were very wormy, giving but 13.51 per cent of fruit free from larvæ.

The sprayed fruit was well protected against the calyx entrance worms except in plat VIII. With this exception, the percentage of wormy apples infested at the calyx in the sprayed plats varied from 3.72 to 5.92. The unsprayed plat produced 55.06 per cent of wormy fruit infested at the calyx.

TABLE 4.—*Summary of results of spraying for the codling moth, Johnson orchard, Grand Valley of Colorado, 1915.*

Plat.	Number of trees examined.	Total number of apples examined.	Total number of worms (including extra).	Average number of worms for all apples.	Average number of worms for wormy apples.	Per cent of worms (including extra) entering apples.			Per cent of wormy apples infested.			Total number of stings.	Average number of stings for all apples.	Per cent of worm-free apples free from stings.	Per cent of all apples free from worms
						At calyx.	At side.	At stem.	At calyx.	At side.	At stem.				
I........	5	4,208	2,952	0.70	1.59	2.34	97.43	0.24	3.72	95.91	0.38	5,306	1.26	40.54	55.87
II.......	12	9,356	7,347	.79	1.67	3.17	96.49	.34	5.29	94.38	.34	17,873	1.91	33.56	52.88
III......	6	2,192	844	.39	1.39	3.44	96.09	.47	4.76	94.58	.66	2,067	.94	52.12	72.22
IV......	5	3,174	1,523	.48	1.43	4.14	95.40	.46	5.92	93.52	.56	3,131	.99	44.27	66.48
V........	7	6,005	3,567	.59	1.57	2.75	96.92	.34	4.32	95.24	.44	5,549	.92	53.51	62.21
VI......	7	3,708	2,013	.54	1.50	3.87	95.83	.30	5.81	93.89	.30	3,450	.93	48.50	63.78
VII.....	4	1,785	2,182	1.22	1.86	2.38	97.25	.37	4.42	95.15	.43	2,098	1.18	56.49	34.17
VIII....	3	1,601	2,308	1.44	2.00	6.50	93.15	.35	12.98	86.76	.26	1,320	.82	52.36	27.80
IX......	10	7,613	3,438	.45	1.43	3.72	95.75	.52	5.32	94.18	.50	7,337	.96	49.39	68.41
X.......	3	2,820	5,077	1.80	2.08	26.45	72.31	1.24	55.06	43.87	1.07	333	.12	90.03	13.51

In the treated plats over 90 per cent of the worms actually infesting the fruit gained entrance through the side of the apple and less than 7 per cent entered by way of the calyx. In untreated plat X 72.31 per cent of the larvæ entered through the side of the fruit and 26.45 per cent through the calyx end. It will thus be seen from these data that one of the chief difficulties in controlling the codling moth in the Grand Valley of Colorado is to prevent the larvæ from entering the apple through the side.

In the plats where arsenate of lead was employed the average number of larvæ for worm-infested fruit varied from 1.39 to 1.67, whereas in the arsenate of lime plats this average was increased to 1.86 and 2, and in the unsprayed plat there was a further increase to 2.08 larvæ for each wormy apple. The higher the percentage of apples free from worms the lower the average number of worms per apple. Thus in plat III, where the best control was obtained and where 72.22 per cent of apples were free from worms, there was an average of only 0.39 larva per apple, and in plat X, which was unsprayed and yielded but 13.51 per cent of worm-free fruit, there were 1.80 larvæ per apple.

In scoring results, account was taken of the so-called codling moth "sting" (Pl. II). The sting is a shallow excavation extending through the skin of the apple into the flesh to a depth of about one-sixteenth to three thirty-seconds of an inch. It is caused by newly hatched larvæ that only succeed in eating their way through the skin before succumbing to the poison, or, for other reasons, do not penetrate deeper into the fruit. In the sprayed plats the average number of stings per apple varied from 0.82 to 1.91, whereas in the unsprayed plat the average was only 0.12.

It is the belief of the writers that, with a uniform infestation and crop and with other factors equal, the number of stings is directly proportional to the number of worm-free apples. In other words, if the spray treatment is effective, the only indication of worm attack will be found in the sting marks, and these will increase within certain limits as the number of worm-free apples increases. In the case of unsprayed fruit, the worms are not subjected to a poison, and hence what might result in only a sting in a sprayed apple becomes a worm hole in the untreated fruit. It should not be inferred, however, that unsprayed fruit is totally devoid of stings, for sting marks sometimes occur on untreated fruit and may be accounted for by larvæ which start an entrance hole and then change to another place, or by larvæ that, before penetrating very far into the fruit, are blown off by wind, brushed off by foliage, or washed off by heavy rains.

SPRAYING EXPERIMENTS IN 1916.

In 1916 the Gus J. Johnson orchard, at Highland Park, and the J. D. Nettleton orchard, at Fruitvale, were used for experimental purposes.

In the Johnson orchard the principal part of the experimental work was a test of the efficiency of coarse sprays applied with a short rod and Bordeaux nozzle in comparison with mist sprays applied by means of spray poles equipped with whirlpool-disk nozzles.

The short rod referred to consisted of a piece of iron pipe about 1 foot in length, to one end of which was attached a Bordeaux nozzle and to the other a cut-off to which the hose was connected. Under a pressure of 225 to 250 pounds and with the nozzle sufficiently open, the spray was practically a solid stream as it left the nozzle, but broke up more or less as it reached the tree. This type of spraying apparatus had been used by many Grand Valley growers for several seasons in preference to the spray poles, formerly employed, because it rendered spraying less burdensome and increased the speed of the work. The spray gun, which was subsequently developed, is an improvement over the short rod, in that the character of the spray can be readily graduated from fine to coarse.

The spray history of the experiments in the Johnson orchard will be found in Tables 5 and 6.

TABLE 5.—*Spraying schedule for the codling moth, Johnson orchard, Grand Valley of Colorado, 1916.*

Number of plat.	Calyx spray.	Cover sprays—first brood.				Cover sprays—second and third broods.	
	A.	B.	C.	D.	E.	F.	G.
	Petals off, May 2–3.	3 to 4 weeks after A, May 29.	14 days after B, June 12.	18 days after B, June 16.	14 days after C, June 26.	9 to 10 weeks after A, July 8.	34 to 41 days after F, Aug. 11–18.
I	First	Second	Third		Fourth	Fifth	Sixth.
II	do	do	do		do	do	Do.
III	do	do		Third		Fourth	Fifth.
IV	do	do		do		do	Do.
V	do	do				Third	Fourth.
VI	do	do				do	Do.
VII	Check						

TABLE 6.—*Treatment of plats for the codling moth, Johnson orchard, Grand Valley of Colorado, 1916.*

Number of plat.	Spraying materials.	Spraying equipment.	
		Calyx spray.	Cover sprays.
I	Arsenate of lead, powder, 1 pound—50.	Spray poles and Bordeaux nozzles.	Spray poles and whirlpool-disk nozzles.
II	do	Short rod andBordeaux nozzle	Short rod and Bordeaux nozzle.
III	do	Spray poles and Bordeaux nozzles.	Spray poles and whirlpool-disk nozzles.
IV	do	Short rod and Bordeaux nozzle	Short rod and Bordeaux nozzle.
V	do	Spray poles and Bordeaux nozzles.	Spray poles and whirpool-disk nozzles.
VI	do	Short rod and Bordeaux nozzle	Short rod and Bordeaux nozzle.
VII	Check—unsprayed		

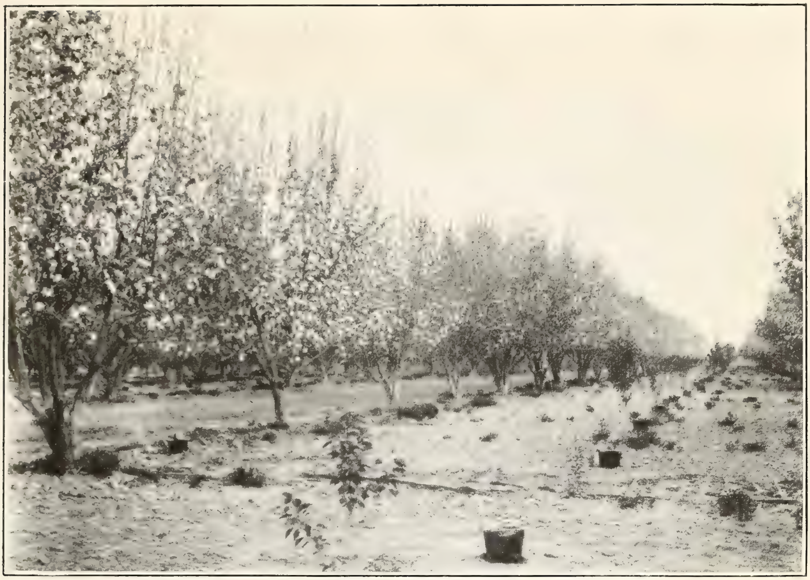

FIG. 1.—THE JOHNSON EXPERIMENTAL ORCHARD.

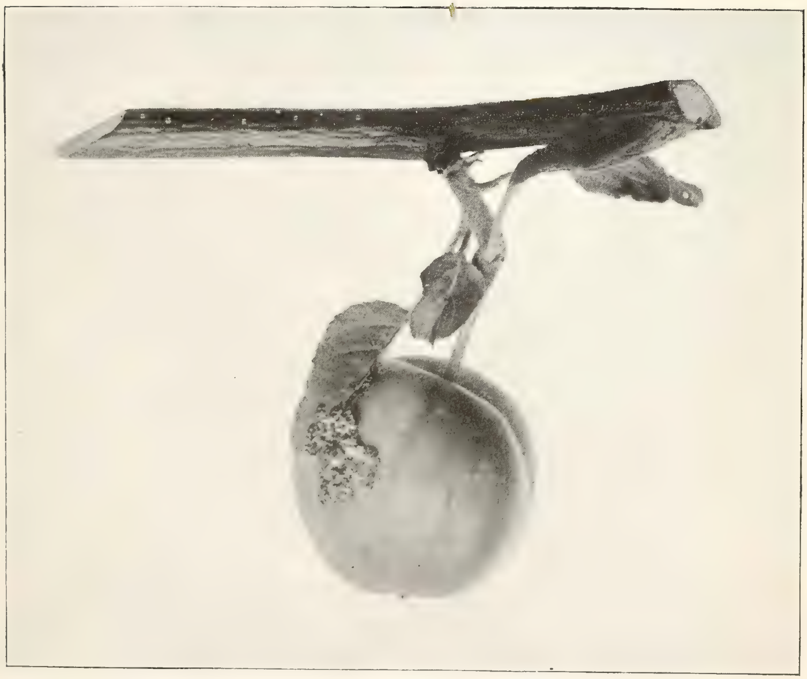

FIG. 2.—APPLE INFESTED BY THE CODLING MOTH, THE YOUNG LARVA HAVING ENTERED FROM THE SIDE.

CONTROL OF THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO.

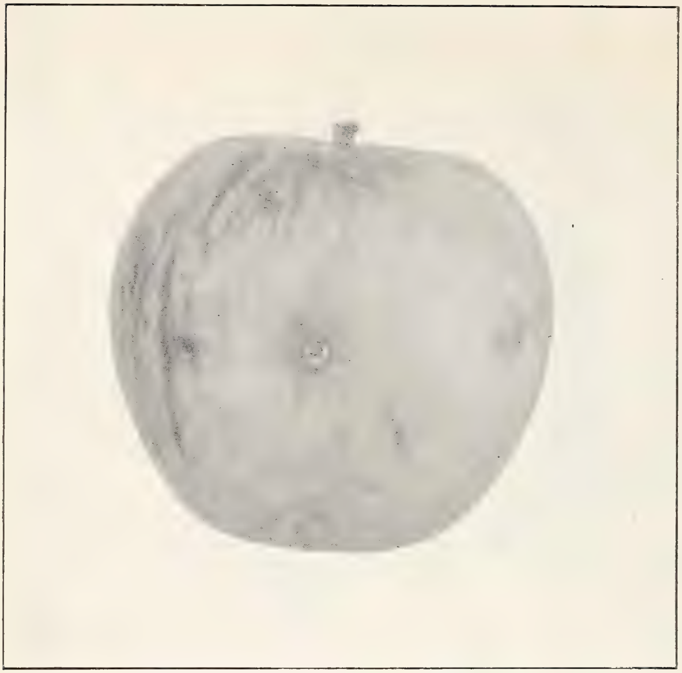

FIG. I.—CODLING MOTH "STING" ON SIDE OF APPLE. NATURAL SIZE.

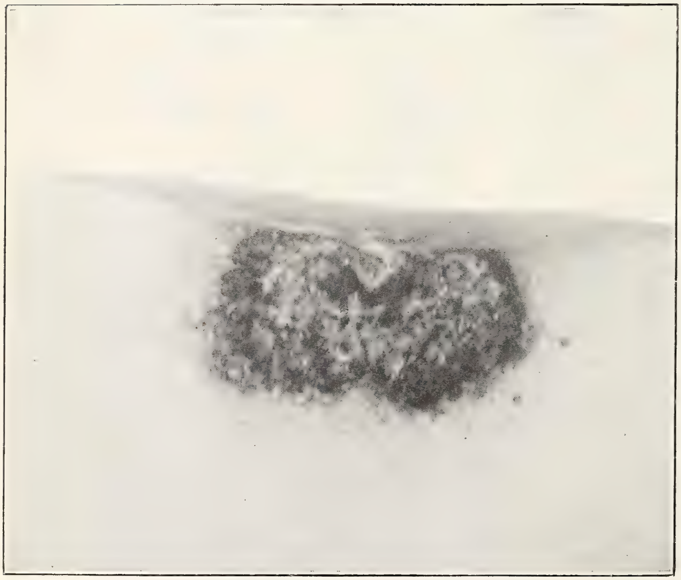

FIG. 2.—VERTICAL SECTION THROUGH A CODLING MOTH "STING." ENLARGED.

CONTROL OF THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO.

By reference to Table 7 it will be noted that in each instance the coarse sprays, as applied with the short rod and Bordeaux nozzle, gave control inferior to that on the plats treated with the poles and whirlpool-disk nozzles. Thus, plat I, fine spray, yielded 89.48 per cent of fruit free from worms in comparison with 79.54 per cent in plat II, which was treated with the coarse spray. In plat III, sprayed with the disk nozzles, there was 85.05 per cent of uninfested fruit, whereas in plat IV, treated by means of the Bordeaux nozzle, there was but 71.06 per cent of fruit free from worms. Again, in plat V, which was treated with the fine spray, there was 89.70 per cent of worm-free fruit in comparison with 81.43 per cent in plat VI, which was sprayed with the Bordeaux nozzle. The untreated plat, plat VII, produced 30.98 per cent of fruit free from worms.

It is the belief of the writers that the coarse sprays do not adhere so readily to the fruit, especially to the waxy skin of apples of the Ben Davis type, as do the fine mist sprays. It is believed further that the distribution of the poison is more thorough with the spray poles and disk nozzles than with the short rod and Bordeaux nozzle.

The results of this experiment considered as a whole seem to show that three cover sprays were more efficient than five. But this anomaly may perhaps be accounted for by the fact that there was no fruit in plats V and VI the preceding year, it having been destroyed by the spring freezes; hence, there being no overwintering larvæ on these trees, the infestation came solely from moths that migrated from other trees.

A further study of Table 7 will show, as in the experiments of 1915 (Table 4), that the average number of worms per apple was lowest where the best control was obtained, with a range in this respect among the sprayed plats of from 0.14 to 0.40. In the unsprayed plat there was an average of 1.43 worms per apple. The spray material readily checked the worms from gaining entrance through the calyx, over 90 per cent of the larvæ having entered the fruit through the side. In the sprayed plats from 2 to 9.99 per cent of the wormy fruit was infested at the calyx while in the unsprayed plat 28.43 per cent of the wormy fruit was caused by larvæ that entered by way of the calyx.

The average number of stings in the sprayed plats for all apples varied from 0.34 to 0.82 and in the unsprayed plat the average number was 0.23.

TABLE 7.—*Summary of results of spraying for the codling moth, Johnson orchard, Grand Valley of Colorado, 1916.*

Plat.	Number of trees examined.	Total number of apples examined.	Total number of worms (including extra).	Average number of worms for all apples.	Average number of worms for wormy apples.	Per cent of worms (including extra) entering apples.			Per cent of wormy apples infested.			Total number of stings.	Average number of stings for all apples.	Average number of stings for stung apples.	Per cent of wormy apples free from sting	Per cent of worm-free apples free from stings.	Per cent of all apples free from worms.	Per cent of all apples free from stings.	Per cent of all apples free from worms and stings.
						At calyx.	At side.	At stem.	At calyx.	At side.	At stem.								
I	10	12,156	1,705	0.14	1.33	3.16	95.85	0.99	4.22	94.61	1.17	6,384	0.53	1.72	57.78	70.82	89.48	69.43	63.35
II	5	6,066	1,601	.26	1.29	7.74	91.07	1.19	9.99	88.56	1.45	3,572	.59	1.69	63.42	65.60	79.54	65.15	52.18
III	10	12,196	2,386	.20	1.31	1.60	97.53	.88	2.08	96.76	1.16	6,873	.56	1.70	56.56	68.70	85.05	66.88	58.43
IV	5	4,253	1,693	.40	1.38	2.60	96.69	.71	3.57	95.45	.98	3,497	.82	1.91	56.16	57.74	71.06	57.00	41.03
V	10	16,014	2,209	.14	1.34	1.49	97.74	.77	2.00	97.03	.97	5,439	.34	1.50	63.13	79.07	89.70	77.43	70.93
VI	5	3,700	898	.25	1.31	2.23	97.21	.56	2.91	96.36	.73	1,929	.52	1.60	63.90	68.27	81.43	67.46	55.59
VII	4	3,954	5,669	1.43	2.08	13.69	85.52	.79	28.43	70.87	.70	905	.23	1.32	78.78	91.10	30.98	82.60	28.22

A series of experiments was conducted in the Nettleton orchard, but the results were largely vitiated by frosts during May shortly after the setting of the fruit. As a consequence of the low temperatures, small frost pits or cracks in the epidermis developed in much of the fruit, particularly around the calyx end of the apple. It was practically impossible to force the spray material into these pits which thus served as an ideal place of entrance for the worms. Since the frosted fruit was unevenly distributed in the several plats, there was no fair basis on which to draw a comparison of the value of the different treatments.

SPRAYING EXPERIMENTS IN 1917.

The major part of the experimental spray work during the season of 1917 was done in the orchard of the George Smith estate, at Orchard Mesa. This orchard consisted of approximately 20 acres of Ben Davis apple trees about 20 years of age and of fairly uniform size and vigor. The orchard was divided into 17 blocks, or plats, all of which were treated, except the two check plats XVI and XVII, located in diagonally opposite corners of the orchard. The treatment of the several plats and the schedule of applications are presented in Tables 8 and 9.

A power sprayer delivering about 225 pounds pressure was employed in all of the liquid-sprayed plats, and a power dusting machine was used in the three dust-treated plats. With the exception of plats XIV and XV, which were sprayed by the owner, all of the plats were cared for by the experimental force. In the first or calyx treatment the sprayed plats were sprayed by means of two spray poles, equipped with Bordeaux nozzles, one of which was operated from the spray tower and the other from the ground. In applying the cover sprays, the Bordeaux nozzles were replaced by the whirlpool-disk type nozzles, except in plats XIV and XV, which were treated by the owner. In plat XIV the use of the Bordeaux nozzles was continued, for the cover applications, throughout the season; in plat XV a spray gun, operated from the ground, was employed for all cover sprays.

TABLE 8.—*Spraying schedule for codling moth, Smith orchard, Grand Valley of Colorado, 1917.*

Number of plat.	Calyx spray.	Cover sprays, first brood.				Cover sprays, second and third broods.			
	A.	B.	C.	D.	E.	F.	G.	H.	I.
	Petals off May 24–29.	19 to 22 days after A, June 12–15.	11 to 13 days after B, June 23–25.	16 days after B, June 28.	10 to 13 days after C, July 3–6.	8 weeks after A, July 18–20.	27 days after F, Aug. 14.	36 days after F, Aug. 23–25.	21 days after G, Sept. 4.
I	First	Second	Third		Fourth	Fifth		Sixth	Seventh.
II	do	do	do		do	do		do	
III	do	do	do		do	do		do	
IV	do	do	do		do	do		do	
V	do	do		Third		Fourth		Fifth	
VI	do	do	Third		Fourth	Fifth		Sixth	
VII	do	do	do		do	do		do	
VIII	do	do		Third		Fourth		Fifth	
IX	do	do	Third		Fourth	Fifth	Sixth		
X	Calyx spray omitted.	First	Second		Third	Fourth		Fifth	
XI	First	Second	Third		Fourth	Fifth		Sixth	
XII	do	do	do		do	do		do	
XIII	do	do	do		do	do		do	
XIV	do	do	do		do	do		do	
XV	do	do	do		do	do		do	
XVI	Check—unsprayed.								
XVII	do								

TABLE 9.—*Treatment of plats for codling moth, Smith orchard, Grand Junction, Colo., 1917.*

Number of plat.	Spray materials and supplemental control measures.	Spraying and dusting equipment.	
		Calyx spray.	Cover sprays.
I	Arsenate of lead, powder, 1 pound—50, and codling moth traps.	Spray poles and Bordeaux nozzles.	Spray poles and whirlpool-disk nozzles.
II	Arsenate of lead, powder, 1 pound—50	do	Do.
III	Nicotine sulphate, 40 per cent, ½ pint—50	do	Do.
IV	Arsenate of lead, powder, 1 pound—50, and nicotine sulphate, 40 per cent, ½ pint—50.	do	Do.
V	Arsenate of lead, powder, 1 pound—50, and codling moth traps.	do	Do.
VI	Arsenate of lead, powder, 1 pound—50, and fish-oil soap, 2 pounds—50.	do	Do.
VII	Arsenate of lime, powder, ¾ pound—50	do	Do.
VIII	Arsenate of lead, powder, 1 pound—50	do	Do.
IX	do	do	Do.
X	do	Calyx spray omitted.	Do.
XI	Arsenate of lead, 20 per cent, and hydrated lime, 80 per cent.	Power dusting machine.	Power dusting machine.
XII	Arsenate of lead, 15 per cent, and hydrated lime, 85 per cent.	do	Do.
XIII	Arsenate of lead, 10 per cent, and hydrated lime, 90 per cent.	do	Do.
XIV	Arsenate of lead, powder, 1 pound—50	Spray poles and Bordeaux nozzles.	Spray poles and Bordeaux nozzles.
XV	do	do	Spray gun.
XVI	Check—unsprayed		
XVII	do		

All the plats, except the unsprayed checks and plat X, were given the calyx treatment. The total number of applications varied from five to seven, with six in the majority. Plats I, II, III, and IV were given the same number of applications, three cover sprays for the first brood and two for the second and third broods. Plats V and VIII had but four cover sprays of lead arsenate, two for the first brood and two for the later broods, and in addition plat V was provided with the codling-moth trap applied to each tree. Plats VI and VII were sprayed throughout the season at the same time as plats I to IV, but, as described later, received different treatment. Plat IX received the largest number of applications, three cover sprays for the first brood and the same number for the second and third broods, making a total of six cover treatments. Plat X was given five cover sprays, but, as previously mentioned, the calyx treatment was omitted. Plats XI, XII, and XIII were given treatment at the same time as the other plats having five cover applications, but the dusting method was substituted for the liquid.

Arsenate of lead, powder, at the rate of 1 pound to 50 gallons of water was used in all of the sprayed plats, except plat VII, in which arsenate of lime, powder, three-fourths pound to 50 gallons, was employed, and plat III, where 40 per cent nicotine sulphate, diluted 1 part in 800 parts of water, was used. Forty per cent nicotine sulphate at this strength was also used with arsenate of lead in plat IV, and in plat VI fish-oil soap, 2 pounds to 50 gallons, was used as a spreader and sticker. Codling-moth traps, described on pages 35–38, were used in plats I and V. Plats XI, XII, and XIII were dusted with arsenate of lead mixed with hydrated lime as a filler in the proportions shown in Table 9. In plat XI a dust mixture containing 20 per cent of arsenate of lead and 80 per cent of hydrated lime was used; in plat XII, the arsenate of lead was decreased to 15 per cent and the hydrated lime increased to 85 per cent. Plat XIII was treated with 10 per cent of arsenate of lead and 90 per cent of hydrated lime. Plats XIV and XV were sprayed by the owner with arsenate of lead and, as previously stated, plats XVI and XVII were untreated throughout the season.

The summary of results of these experiments is presented in Table 10.

TABLE 10.—*Summary of results of spraying for the codling moth, Geo. Smith Estate Orchard, Grand Valley of Colorado, 1917.*

Plat.	Number of trees examined.	Total number of apples examined.	Total number of worms (including extra).	Average number of worms for all apples.	Average number of worms for wormy apples.	Percentage of worms (including extra) entering apples.			Percentage of wormy apples infested.			Total number of stings.	Average number of stings for all apples.	Average number of stings for stung apples.	Percentage of wormy apples free from stings.	Percentage of worm-free apples free from stings.	Percentage of all apples free from worms.	Percentage of all apples free from stings.	Percentage of all apples free from worms and stings.
						At calyx.	At side.	At stem.	At calyx.	At side.	At stem.								
I	8	28,233	10,224	0.36	1.25	2.26	96.82	0.92	2.82	96.22	0.96	20,468	0.72	1.77	59.44	59.04	70.99	59.16	41.92
II	8	23,508	11,869	.50	1.33	2.95	96.52	.53	3.93	95.67	.40	25,082	1.07	1.99	51.16	43.54	62.10	46.42	27.04
III	8	29,881	22,967	.77	1.24	18.07	79.91	2.02	22.39	75.77	1.84	3,902	.13	1.15	88.53	88.79	37.97	88.62	33.71
IV	8	24,003	8,165	.34	1.22	4.03	94.99	.98	4.89	94.17	.94	12,525	.52	1.64	65.86	69.15	72.05	68.09	49.82
V	8	36,977	12,561	.34	1.23	2.65	96.57	.78	3.25	95.93	.82	18,761	.51	1.52	67.68	66.17	72.29	66.60	47.84
VI	8	34,367	8,884	.26	1.18	7.82	90.82	1.36	9.22	89.37	1.41	21,978	.64	1.63	66.31	59.21	78.06	60.77	46.22
VII	8	31,502	27,184	.86	1.36	6.39	92.76	.85	8.68	90.63	.69	21,770	.69	1.74	62.97	55.66	36.51	60.30	20.33
VIII	8	38,874	12,629	.32	1.23	3.93	95.37	.70	4.81	94.48	.71	24,450	.63	1.63	63.41	60.69	73.49	61.41	44.61
IX	8	47,773	13,206	.28	1.18	4.85	94.25	.90	5.71	93.45	.84	30,170	.63	1.65	65.00	60.68	76.53	61.69	46.44
X	8	37,628	25,334	.67	1.26	29.83	69.14	1.03	37.42	61.60	.98	25,878	.69	1.68	63.02	54.73	46.33	59.18	25.36
XI	8	34,291	26,862	.78	1.47	14.74	84.09	1.17	20.65	78.39	.96	16,972	.49	1.55	70.61	64.54	40.75	68.13	26.30
XII	8	41,252	38,149	.92	1.41	14.61	84.39	1.00	20.65	78.39	.96	20,012	.49	1.56	71.11	64.85	34.58	68.94	22.43
XIII	8	44,413	59,498	1.34	1.57	22.29	76.73	.98	34.87	64.40	.73	20,039	.45	1.59	72.83	64.86	14.38	71.69	9.33
XIV	8	22,194	17,928	.81	1.35	6.39	92.80	.81	8.64	90.59	.77	27,237	1.23	2.25	50.84	37.19	40.21	45.35	14.96
XV	8	23,725	24,675	1.04	1.50	5.81	93.30	.89	8.66	90.67	.67	21,253	.90	2.06	59.23	50.29	30.22	56.52	15.20
XVI	4	20,209	28,669	1.42	1.56	30.26	68.59	1.15	47.09	52.12	.79	2,907	.14	1.22	87.87	91.15	8.83	88.16	8.06
XVII	4	13,673	20,535	1.50	1.64	28.92	69.98	1.15	47.50	51.96	.54	2,084	.15	1.21	87.28	88.88	8.54	87.42	7.60

Plat VI, which was sprayed six times with arsenate of lead and fish-oil soap, yielded 78.06 per cent of apples free from worms, which was the highest percentage of uninfested fruit in the orchard. Also the average number of worms for all apples was as low in this plat as in any other. The percentage of all apples free from worms and stings in plat VI was 46.22, which was not as high as that obtaining in plats IX (46.44 per cent), V (47.84 per cent), and IV (49.82 per cent). Plat IX produced the next best results, 76.53 per cent of all the fruit being free from worms as a result of seven applications of arsenate of lead; plat V, with five treatments supplemented with the codling-moth trap, yielded 72.29 per cent of uninfested fruit; plat IV, 72.05 per cent, with six applications of arsenate of lead and nicotine sulphate. Two other plats, I and VIII, produced 70.99 and 73.49 per cent of worm-free fruit, respectively; the former being sprayed six times with arsenate of lead, supplemented with the codling-moth trap, and the latter having only five applications of arsenate of lead. Plat II, which received six applications of arsenate of lead, yielded but 62.10 per cent of worm-free fruit and but 27.04 per cent of fruit free from worms and stings. Apparently the infestation in this plat was somewhat heavier than that which prevailed in some of the other plats. Plat III was treated six times with nicotine sulphate, which resulted in but 37.97 per cent of fruit free from worms. The percentage of this fruit free from stings was relatively high (88.62 per cent), a condition which would naturally be expected, owing to the fact that the majority of the larvæ that attacked the fruit were able to enter it without being killed by the spray. Attention is called to the fact that in this plat (plat III) 18.07 per cent of all the worms infesting the apples entered by way of the calyx end and that 22.39 per cent of the wormy apples were infested at the calyx. In plat VII arsenate of lime was used with unsatisfactory results, there being 36.51 per cent of worm-free apples and only 20.33 per cent of the fruit free from worms and stings. Plat X was sprayed at the same time as the plats that had six treatments, except that the calyx application was omitted, thus making a total of five treatments. The percentage of worm-free fruit was 46.33, and the percentage of all apples free from worms and stings was 25.36. It is worthy of note that the percentage of worms entering the calyx was high (29.83 per cent), and that 37.42 per cent of the wormy apples were infested at the calyx.

Plats XI, XII, and XIII were dusted six times with mixtures containing 20, 15, and 10 per cent of arsenate of lead, respectively. The results of these treatments indicate quite conclusively that dusting is unsatisfactory for the control of the codling moth in the Grand Valley. With as much as a 20 per cent lead arsenate mixture only 40.75 per cent of the fruit was free from worms; with a 15 per cent lead arsenate mixture there was 34.58 per cent of worm-free fruit;

and with a mixture containing 10 per cent of lead arsenate there was only 14.38 per cent of uninfested fruit, all of which would indicate practically no control. Furthermore, the dust was not nearly so effective as the liquid sprays in preventing the entrance of worms at the calyx.

The two plats sprayed by the grower, plats XIV and XV, produced a lower percentage of control than those treated by the experimental staff. Plat XIV, in which spray poles and Bordeaux nozzles were used throughout the season, yielded 40.21 per cent of uninfested fruit, whereas plat XV, in which the spray gun was employed for the cover sprays, gave but 30.22 per cent of worm-free fruit.

The abundance of the codling moth in this orchard is indicated in plats XVI and XVII, both of which were untreated and which produced but 8.83 and 8.54 per cent of worm-free fruit. The number of stings in these plats, as was to be expected, was not large, there being 88.16 per cent of fruit free from stings in plat XVI and 87.42 per cent in plat XVII. It will be further noted that in these plats the percentage of calyx worms was large, 30.26 and 28.92 per cent, respectively, with 47.09 and 47.50 per cent of the wormy apples infested at the calyx end.

Codling-Moth Trap Experiments in 1917.

A section of the J. B. Hunter orchard near Fruita, Colo., consisting of Ben Davis and Gano apple trees, was divided into three plats. Plat I, containing 60 trees, was banded and sprayed; plat II, having 108 trees, was provided with the codling-moth trap and sprayed; while plat III, 99 trees, received no other treatment than five spray applications as described below.

The spray applications, five in all, were made by the grower on all the plats as follows: Calyx spray applied June 1–2; first cover spray June 14–16; second cover spray July 11; third cover spray July 27; fourth cover spray August 16. A power sprayer was used throughout the season and this was equipped with Bordeaux nozzles for the calyx application and whirlpool-disk type nozzles having a large aperture disk for all of the cover treatments.

The data obtained from the examination of the dropped and harvested fruit from eight trees in each plat will be found in Table 11. It will be noted therein that plat III, which had only the spray treatment, produced 76.56 per cent of fruit free from worms, a higher percentage than that of plats I and II, which received theoretically better treatments. There is no logical explanation for these results other than the possibility of unevenness of infestation and yield of fruit.

TABLE 11.—*Summary of results of spraying for the codling moth, Hunter orchard, Grand Valley of Colorado, 1917.*

Plat.	Number of trees examined.	Total number of apples examined.	Total number of worms (including extra).	Average number of worms for all apples.	Average number of worms for wormy apples.	Percentage of worms (including extra) entering apples.			Percentage of wormy apples infested.			Total number of stings.	Average number of stings for all apples.	Average number of stings for stung apples.	Percentage of wormy apples free from stings.	Percentage of worm-free apples free from stings.	Percentage of all apples free from worms.	Percentage of all apples free from stings.	Percentage of all apples free from worms and stings.
						At calyx	At side.	At stem.	At calyx.	At side.	At stem.								
I	8	24,345	13,446	0.55	1.29	16.91	81.91	1.18	21.95	77.01	1.04	15,297	0.63	1.59	57.98	62.76	57.44	60.72	36.04
II	8	38,781	15,209	.39	1.31	30.43	68.10	1.47	39.79	59.06	1.15	12,942	.33	1.37	74.73	76.13	70.00	75.71	53.29
III	8	45,689	14,056	.31	1.31	22.52	75.82	1.66	29.57	68.81	1.62	15,812	.35	1.38	71.19	76.09	76.56	74.95	58.26

NOTE.—See p. 16 for treatments.

TABLE 12.—*Collections of codling moth larvæ and pupæ from banded trees, Plat I, Hunter orchard, Grand Valley of Colorado, 1917.*

Tree No.	Date of collection.																
	July 3.		July 12.		July 18.		July 28.		Aug. 7.		Aug. 17.		Aug. 27.		Sept. 6.		Nov. 21, larvæ.
	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	
1	6	....	21	7	21	....	17	7	10	5	10	....	20	....	13	....	44
2	12	....	31	7	14	3	20	8	6	5	11	3	10	....	9	....	48
3	58	1	55	17	27	3	33	5	10	2	20	2	10	....	14	....	67
4	11	....	29	6	17	1	18	6	2	1	3	....	11	....	20	....	34
5	5	....	36	3	....	....	15	7	6	2	11	2	9	....	19	....	37
6	....	1	29	5	18	2	4	3	19	2	7	2	16	....	8	....	28
7	3	1	2	3	10	....	8	8	6	2	5	2	4	....	8	....	27
8	2	....	10	....	9	3	13	7	8	6	16	1	7	....	24	....	26
9	2	....	22	14	30	4	22	6	9	12	28	7	14	....	13	....	47
10	12	....	10	2	21	1	37	8	15	3	32	5	11	....	37	....	38
11	7	....	10	4	11	2	12	3	9	7	18	4	4	....	4	....	16
12	23	....	18	12	31	4	13	8	6	4	8	3	8	....	9	....	26
13	5	....	27	4	36	5	25	8	12	6	12	3	8	....	15	....	25
14	....	....	18	2	6	....	14	9	3	4	3	4	2	....	16	....	36
15	1	1	6	3	27	2	10	7	8	5	10	8	13	....	7	2	25
16	1	....	8	3	12	2	6	4	6	8	9	1	5	....	4	....	16

TABLE 12.—*Collections of codling moth larvæ and pupæ from banded trees, Plat I, Hunter orchard, Grand Valley of Colorado, 1917*—Continued.

Tree No.	Date of collection.																
	July 3.		July 12.		July 18.		July 28.		Aug. 7.		Aug. 17.		Aug. 27.		Sept. 6.		Nov. 21, larvæ.
	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	
17	15	1	12	4	10	6	6	2	11	6	17	2	11	....	14	....	43
18	2	....	12	3	17	2	7	2	4	5	26	3	21	....	18	....	54
19	1	....	8	3	13	....	5	5	6	4	15	1	20	....	19	....	52
20	1	....	6	1	8	1	10	14	7	13	16	2	10	....	13	....	35
21	2	....	21	6	24	2	16	11	6	5	33	4	12	1	15	....	38
22	2	....	24	7	12	....	14	5	10	5	24	4	16	....	15	....	46
23	1	3	13	1	24	4	12	11	6	2	10	1	2	....	11	....	18
24	2	....	17	....	10	2	3	8	2	1	13	....	6	....	26	....	13
25	10	....	9	1	17	....	6	5	5	3	8	3	4	....	21	....	15
26	4	1	23	7	13	....	15	3	3	3	21	2	5	....	25	....	10
27	10	1	12	10	13	2	15	13	2	5	8	1	12	....	11	1	30
28	1	....	3	....	2	....	5	4	8	5	14	2	6	....	7	....	21
29	6	....	24	11	29	5	17	6	9	2	12	2	22	....	12	....	47
30	28	10	28	15	34	7	28	8	12	8	16	4	11	....	37	....	37
31	13	2	9	6	33	4	13	5	7	....	21	4	16	....	22	....	19
32	15	1	47	13	19	2	23	7	12	7	35	15	15	1	15	....	49
33	5	1	16	6	10	....	16	12	4	2	15	1	12	....	19	....	20
34	5	1	24	7	16	4	15	7	7	2	38	3	18	....	22	....	30
35	11	....	26	11	13	....	24	9	7	4	34	2	12	....	24	....	40
36	2	....	15	6	14	3	....	1	3	2	16	5	16	1	3	....	68
37	2	....	5	....	5	....	1	5	3	....	5	3	2	....	8	....	12
38	14	....	13	5	11	7	16	9	7	6	20	3	10	....	18	....	29
39	12	2	10	6	11	4	14	17	7	4	8	3	5	....	10	....	52
40	2	....	9	2	6	....	4	7	6	5	11	3	6	....	10	....	20
41	1	1	7	2	17	3	10	5	7	5	16	2	12	1	6	....	29
42	2	....	9	5	6	3	15	2	5	6	11	3	9	....	12	....	21
43	13	1	16	6	18	5	16	....	3	7	6	1	4	....	12	....	10
44	....	....	20	6	7	1	10	6	5	3	11	....	22	1	10	....	12
45	3	....	38	16	18	7	18	10	5	12	....	4	7	2	7	....	23
46	7	2	32	10	9	2	18	12	4	8	6	1	2	....	5	....	18
47	4	....	10	3	....	1	3	4	6	2	4	2	3	....	9	....	15
48	2	....	14	5	13	3	11	10	....	....	4	....	2	....	5	....	7
49	....	....	3	....	....	1	1	6	....	1	1	....	2	....	3	....	6
50	5	....	11	13	9	1	8	5	2	3	3	2	1	....	4	....	11
51	9	1	46	30	25	4	35	19	10	3	13	5	17	....	13	....	32
52	12	4	27	14	9	2	14	13	10	3	27	8	12	....	35	....	13
53	8	1	19	17	7	2	26	11	14	9	13	7	13	2	19	....	25
54	11	....	42	38	20	2	37	18	13	6	19	7	1	....	27	....	35

55	8	5	43	21	39	4	38	30	12	9	18	2	16	....	24	....	48
56	1	4	14	3	16	2	6	5	....	....	1	....	2	....	8	....	20
Total	400	46	1,069	412	867	130	818	436	385	250	792	164	547	9	814	3	1,663

Total number larvæ for season	7,355	Total number all stages for season	8,805
Total number pupæ for season	1,450	Average number all stages per tree	157.23

TABLE 13.—*Collections from codling moth traps, Plat II, Hunter orchard, Grand Valley of Colorado, 1917.*

Tree No.	Date of collection.															
	July 12.		July 18.		July 28.		Aug. 7.		Aug. 17.			Aug. 27.		Sept. 6.		Nov. 21, larvæ.
	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Moths.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	
1	15	12	24	2	16	31	12	3	5	2	....	15	....	8	....	65
2	27	6	25	4	6	17	11	4	15	2	....	24	1	19	1	84
3	33	21	26	5	27	27	6	8	11	6	....	18	....	43	....	123
4	10	17	18	5	13	14	10	10	5	2	....	9	....	20	....	49
5	36	5	30	5	15	14	10	5	12	6	....	24	....	42	2	121
6	9	3	15	....	14	20	5	2	15	....	....	19	1	20	....	75
7	25	2	19	5	20	22	10	7	10	1	....	15	2	13	....	18
8	24	16	19	3	6	21	8	4	3	1	....	3	....	19	....	19
9	9	7	11	1	13	10	3	4	4	1	1	9	....	36	....	73
10	12	11	14	1	15	15	6	6	10	1	....	21	....	33	....	90
11	16	3	27	7	14	12	6	8	10	2	....	17	1	28	....	90
12	9	....	27	1	7	16	5	2	5	2	....	10	....	20	....	77
13	16	5	17	....	17	14	5	2	8	2	....	10	....	6	....	47
14	17	12	25	4	20	21	9	6	10	2	....	15	....	19	....	61
15	24	13	28	3	10	20	12	4	7	3	1	14	....	22	....	71
16	2	....	6	....	5	9	5	3	5	1	....	5	....	15	....	51
17	6	....	10	2	7	8	5	5	4	1	....	5	....	7	....	29
18	12	3	17	2	15	10	7	5	7	4	....	7	....	5	....	31
19	11	2	15	1	22	21	11	7	17	1	....	15	....	16	....	74
20	7	3	6	2	12	24	7	3	7	1	....	8	....	10	....	44

Total number larvæ for season	3,252	Total number all stages for season	3,941
Total number pupæ for season	687	Average number all stages per tree	197.05
Total number moths for season	2		

In Tables 12 and 13 will be seen the data obtained from examinations of the bands and traps. From 56 banded trees 8,805 larvæ and pupæ, or an average of 157.23, were taken, and from 20 codling-moth traps 3,941 larvæ, pupæ, and moths, or an average of 197.05, were secured. The destruction of so large a number of individuals should aid gradually in obtaining better control despite the fact that the experimental data for this, the first year, indicate otherwise.

Part of the orchard of Charles Lamb near Highland Park was also used for the codling-moth trap experiments. This was sprayed by the grower who used the short rod equipped with a Bordeaux type of nozzle in making all the spray applications. In addition to the calyx treatment, six cover sprays were applied. Plat I was sprayed and trapped, plat II was sprayed, and plat III was untreated.

The results of the fruit examinations of eight trees in each of plats I and II and four trees in plat III are given in Table 14. In plat I, which was sprayed and trapped, 50.54 per cent of the dropped and harvested fruit was free from worm infestation; whereas in plat II, which was merely sprayed, there was 64.54 per cent of uninfested fruit. The unsprayed plat produced 11.45 per cent of fruit free from larvæ.

It will be noted in Table 15 that 5,512 larvæ, pupæ, and moths were collected from 20 codling-moth traps and that the average per trap was 275.6.

In the Smith experimental orchard, where the principal spraying experiments of 1917 were conducted, examinations were made of 20 codling-moth traps in plat I and of 15 in plat V. The results are presented in Tables 16 and 17, in which it will be seen that in plat I, 6,186 larvæ, pupæ, and moths, or an average of 309.3 per trap, were secured, while in plat V a total of 4,673 or an average per trap of 311.53 individuals were captured.

TABLE 14.—*Summary of results of spraying for the codling moth, Lamb orchard, Grand Valley of Colorado, 1917.*

Plat.	Number of trees examined.	Total number of apples examined.	Total number of worms (including extra).	Average number of worms for all apples.	Average number of worms for wormy apples.	Percentage of worms (including extra) entering apples.			Percentage of wormy apples infested.			Total number of stings.	Average number of stings for all apples.	Average number of stings for stung apples.	Percentage of wormy apples free from stings.	Percentage of worm-free apples free from stings.	Percentage of all apples free from worms.	Percentage of all apples free from stings.	Percentage of all apples free from worms and stings.
						At calyx.	At side.	At stem.	At calyx.	At side.	At stem.								
I	8	15,380	9,544	0.62	1.25	3.51	95.32	1.17	4.40	94.35	1.25	10,672	0.69	1.59	66.63	46.82	50.54	56.62	23.69
II	8	20,578	8,596	.42	1.17	5.27	93.12	1.61	6.21	92.21	1.58	14,003	.68	1.72	67.90	56.21	64.54	60.35	36.28
III	4	8,949	11,752	1.31	1.48	24.99	73.69	1.32	37.11	61.56	1.33	1,381	.15	1.23	87.57	86.15	11.45	87.42	9.87

NOTE.—See page 21 for treatments.

TABLE 15.—*Collections from codling moth traps, plat I, Lamb orchard, Grand Valley of Colorado, 1917.*

Tree No.	Date of collection.																
	July 6.		July 16.		July 26.			Aug. 5.			Aug. 15.		Aug. 25.			Sept. 4.		Nov. 19, larvæ.
	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Moths.	Larvæ.	Pupæ.	Moths.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Moths.	Larvæ.	Pupæ.	
1	4	1	36	34	24	38		10	19		9	1	12	1		14		90
2	9	1	20	19	15	21		12	7		2	1	11			25		62
3	31	2	26	40	13	27	1	7	11		5	3	27	4		35	2	146
4	24	2	34	34	11	23		18	17		5	5	15	5	1	24		73
5	29	4	43	60	23	31		5	13	1	3	5	13	1		17		82
6	11		11	19	31	27		18	16		4	4	16	1	1	15	4	78
7	13	1	21	40	13	24		8	13		11	8	13	3		18		76
8	13		17	28	11	31		15	11		6	3	12	1		26		66
9	27	5	19	52	18	33		2	8		4	2	19			34	1	137
10	12	2	21	62	4	23		8	13		4	6	20	3		35		116
11	9	4	4	18	6	6		3	2		3	1	2	2		13		66
12	9	5	29	38	26	9		6	5		5	3	15			27		88
13	5		24	20	2	11		6	5		1		9			11		44
14	9		17	30	37	38	1	14	17		4	4	8	3		32		80
15	9	3	31	39	28	49		10	19	1	9	6	14			37		111
16	9	2	18	37	8	14		16	11		4	1	18	3		27		90
17	12	3	12	22	14	15		6	10		4	2	15			18		55
18	7		3	15	11	12		6	6		14	1	19			22		80
19	11	3	20	32	25	30		9	16		11	3	20	3		48	2	115
20	21	4	28	40	15	31		9	10		4	1	34			48		125

Total number larvæ for season	3,962	Total number all stages for season	5,512
Total number pupæ for season	1,542	Average number all stages per tree	275.6
Total number moths for season	8		

TABLE 16.—*Collections from codling moth traps, plat I, Smith orchard, Grand Valley of Colorado, 1917.*

Tree No.	Date of collection.																		
	July 7.		July 17.		July 27.			Aug. 6.			Aug. 16.			Aug. 26.			Sept. 5.		Nov. 20, larvæ.
	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Moths.	Larvæ.	Pupæ.	Moths.	Larvæ.	Pupæ.	Moths.	Larvæ.	Pupæ.	Moths.	Larvæ.	Pupæ.	
1	14	1	10	24	12	15	....	9	13	....	10	....	....	52	....	....	61	....	152
2	10	3	30	30	13	22	1	22	20	1	26	8	....	33	....	....	74	1	238
3	5	3	14	13	10	11	....	6	5	....	7	6	....	26	....	....	82	....	195
4	30	5	35	58	20	30	1	6	18	....	17	6	....	42	2	....	93	....	192
5	25	3	30	42	6	20	1	10	3	....	6	4	2	26	....	1	67	....	121
6	15	1	29	40	14	11	1	5	3	....	17	6	1	29	1	....	44	....	121
7	10	6	15	14	5	9	....	5	4	....	8	1	....	28	1	....	66	....	148
8	8	3	5	11	8	8	1	7	5	....	12	2	....	42	....	....	74	....	168
9	3	1	1	17	2	6	....	4	5	....	11	3	....	27	....	....	56	....	116
10	2	....	15	23	8	11	1	6	5	....	10	2	....	38	....	....	57	....	158
11	2	....	7	4	1	1	....	....	1	....	4	4	....	21	....	....	32	....	71
12	7	1	24	30	3	12	1	2	2	....	6	1	1	28	....	....	48	....	126
13	4	1	6	8	3	5	....	1	3	....	6	....	....	34	1	....	64	....	140
14	8	1	15	25	5	4	....	2	3	....	7	1	....	18	3	....	57	....	167
15	10	4	13	19	2	3	....	7	2	....	2	3	....	25	....	....	50	....	118
16	6	3	7	6	2	9	....	....	1	....	2	1	....	26	1	....	39	....	126
17	2	4	10	13	4	7	....	1	3	....	2	1	....	12	1	....	41	....	77
18	3	3	6	3	3	4	....	3	1	....	2	1	....	12	....	....	45	....	115
19	5	1	12	13	2	4	....	1	3	....	....	1	....	3	....	....	11	....	79
20	17	4	2	26	7	12	....	2	9	....	5	1	....	25	1	1	67	....	162

Total number larvæ for season	5,326	Total number all stages for season	6,186
Total number pupæ for season	845	Average number all stages per tree	309.3
Total number moths for season	15		

TABLE 17.—*Collections from codling moth traps, plat V, Smith orchard, Grand Valley of Colorado, 1917.*

Tree No.	Date of collection.																	
	July 7.		July 17.		July 27.			Aug. 6.		Aug. 16.			Aug. 26.		Sept. 5.			Nov. 20, larvæ.
	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Moths.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Moths.	Larvæ.	Pupæ.	Larvæ.	Pupæ.	Moths.	
1	16	3	27	43	21	30	1	6	11	17	4	1	28	....	76	....	....	220
2	15	1	27	30	13	14	....	13	10	9	8	....	16	....	26	2	....	151
3	15	....	15	29	11	26	....	23	18	24	4	....	41	4	54	1	1	239
4	12	2	22	28	10	12	....	12	6	8	4	....	21	....	50	....	....	146
5	25	6	17	42	11	16	....	11	19	15	6	....	35	1	66	....	....	192
6	9	....	16	27	10	14	....	7	7	18	2	1	50	1	77	....	....	258
7	6	1	6	13	1	8	....	2	6	5	....	....	19	....	30	....	....	115
8	11	6	9	13	3	....	....	3	4	7	1	....	33	1	31	....	....	139
9	7	2	2	1	....	....	....	....	1	8	1	....	17	....	30	....	....	122
10	3	5	3	3	....	1	....	....	2	3	2	....	15	....	28	....	....	89
11	7	9	5	37	8	4	....	1	2	4	3	....	14	1	46	....	....	95
12	6	2	4	11	6	4	....	5	1	7	....	....	21	1	71	....	....	184
13	5	4	11	17	4	16	....	8	3	3	1	....	24	....	60	....	....	164
14	5	1	2	8	....	2	....	2	5	6	1	....	18	....	31	....	....	101
15	....	....	3	11	3	....	....	3	1	1	1	....	13	....	16	....	....	102

Total number larvæ for season	4,017	Total number all stages for season	4,673
Total number pupæ for season	652	Average number all stages per tree	311.53
Total number moths for season	4		

As will be noted in Table 10, plat I yielded 70.99 per cent of fruit free from worms, an improvement in favor of the traps over plat II, which was untrapped but received the same number of spray applications (six in all) and which yielded 62.1 per cent of worm-free fruit. On the other hand, the traps did not improve the results in plat V, which, like plat VIII, received a total of five applications, the yield of worm-free fruit in these two plats being 72.29 per cent and 73.49 per cent, respectively.

From the foregoing experiments it will be seen that the traps captured an average of from 197.05 to 311.53 individuals per tree; but contrary to what might be expected, the reduction in the number of insects was not generally followed by a corresponding decrease in the percentage of wormy fruit. This would appear illogical, and it will therefore be necessary to make further tests covering a longer period of time before the value of the codling-moth traps as a supplementary control measure can be determined.

SPRAYING EXPERIMENTS IN 1918.

The spraying experiments in 1918 were conducted in the Red Cross orchard on a block of Gano trees about 13 years of age. These trees were subdivided into 12 plats, of which 10 were sprayed and the remaining 2 were untreated checks located in diagonally opposite corners of the orchard.

Table 18 shows the treatment given in the different plats. Arsenate of lead, powder, at the rate of 1 pound to 50 gallons was used in all of the sprayed plats, except in plats IX and X where the strength was reduced to one-half pound to 50 gallons. Fish-oil soap at the rate of 2 pounds to 50 gallons was used as a spreader and sticker for the arsenate of lead in plats III, IV, VII, VIII, and IX. The codling-moth trap was applied to all trees in plats I, III, V, and VII.

The sprays were applied by means of a power sprayer delivering about 225 pounds' pressure to two leads of hose. Two spray poles were employed in all treatments, one being operated from the tower and the other from the ground. In the calyx application Bordeaux nozzles were used, but these were replaced by whirlpool disk nozzles for the cover sprays.

As shown in Table 19, plats I to IV received, in addition to the calyx treatment, five cover sprays, three for the first brood and two for the later broods, and plats V to X were given one less cover spray, making a total of four, two of which were applied for the first-brood larvæ and two for protection against the second and third broods.

TABLE 18.—*Treatment of plats for the codling moth, Red Cross orchard, Grand Valley of Colorado, 1918.*

No. of plat.	Spray materials and supplemental control measures.	Spraying equipment.	
		Calyx spray.	Cover sprays.
I	Arsenate of lead, powder, 1 pound—50, and codling-moth traps.	Spray poles and Bordeaux nozzles.	Spray poles and whirlpool disk nozzles.
II	Arsenate of lead, powder, 1 pound—50	do	Do.
III	Arsenate of lead, 1 pound—50, fish-oil soap, 2 pounds—50, and codling-moth traps.	do	Do.
IV	Arsenate of lead, 1 pound—50, and fish-oil soap, 2 pounds—50.	do	Do.
V	Arsenate of lead, powder, 1 pound—50, and codling-moth traps.	do	Do.
VI	Arsenate of lead, powder, 1 pound—50	do	Do.
VII	Arsenate of lead, 1 pound—50, fish-oil soap, 2 pounds—50, and codling-moth traps.	do	Do.
VIII	Arsenate of lead, 1 pound—50, and fish-oil soap, 2 pounds—50.	do	Do.
IX	Arsenate of lead, ½ pound—50, and fish-oil soap, 2 pounds—50.	do	Do.
X	Arsenate of lead, ½ pound—50	do	Do
XI	Check—unsprayed		
XII	do		

TABLE 19.—*Spraying schedule for the codling moth, Red Cross orchard, Grand Valley of Colorado, 1918.*

No. of plat.	Calyx spray.	Cover sprays—first brood.				Cover sprays—second and third broods.	
	A.	B.	C.	D.	E.	F.	G.
	Petals off, May 10-14.	3 to 4 weeks after A, June 3-5.	9 days after B, June 12-13.	12 days after B, June 15-17.	11 days after C, June 23-24.	8 to 9 weeks after A, July 8-11.	35 days after F, Aug 12-15.
I	First	Second	Third		Fourth	Fifth	Sixth.
II	do	do	do		do	do	Do.
III	do	do	do		do	do	Do.
IV	do	do	do		do	do	Do.
V	do	do		Third		Fourth	Fifth.
VI	do	do		do		do	Do.
VII	do	do		do		do	Do.
VIII	do	do		do		do	Do.
IX	do	do		do		do	Do.
X	do	do		do		do	Do.
XI	Check						
XII	do						

The results of these experiments are summarized in Table XX. The best results were obtained in plat IV in which 77.36 per cent of the fruit was free from worms and 60.36 per cent was free from both worms and stings. This plat was sprayed six times with arsenate of lead and fish-oil soap. Plat III, which had a like number of applications of the same materials and in addition was provided with the codling-moth trap, yielded 71.80 per cent of fruit free from worms and only 42.78 per cent free from both worms and stings. None of the other plats produced satisfactory commercial returns, and in plat VIII, which was sprayed five times with arsenate of lead and fish-oil soap, but 21.23 per cent of fruit was free from worm infestation. Plat VI, which was given five applications of arsenate of lead alone, produced 37.88 per cent of fruit free from worms. It will thus be seen that in these experiments the addition of soap did not in all cases increase the percentage of worm-free apples, nor did the codling-moth trap appear to have any distinct value. In plats IX and X the arsenate of lead strength was reduced to one-half pound to 50 gallons, and, all factors being taken into consideration, the results indicate that this strength is as effective as 1 pound to 50 gallons. The unsprayed plats XI and XII produced 8.43 and 24.08 per cent of worm-free fruit, respectively.

The percentage of calyx entrants was somewhat higher in the unsprayed than in the sprayed fruit, but the difference in this respect is not so great as is usually found in spraying experiments for the control of the codling moth. The unsprayed fruit was comparatively free from the codling-moth sting, which is in accord with the experimental data obtained in the preceding years.

TABLE 20.—*Summary of spraying results for the codling moth, Red Cross orchard, Grand Valley of Colorado, 1918.*

Plat.	Number of trees examined.	Total number of apples examined.	Total number of worms (including extra).	Average number of worms for all apples.	Average number of worms for wormy apples.	Percentage of worms (including extra) entering apples.			Percentage of wormy apples infested.			Total number of stings.	Average number of stings for all apples.	Average number of stings for stung apples.	Percentage of wormy apples free from stings.	Percentage of worm-free apples free from stings.	Percentage of all apples free from worms.	Percentage of all apples free from stings.	Percentage of all apples free from worms and stings.
						At calyx.	At side.	At stem.	At calyx.	At side.	At stem.								
I	8	8,466	5,402	0.64	1.49	6.67	92.98	0.35	9.94	89.54	0.52	12,378	1.46	2.90	36.73	59.15	57.22	49.56	33.85
II	8	8,390	5,828	.69	1.81	7.15	92.49	.36	11.76	87.99	.25	12,729	1.52	3.46	35.78	71.15	57.72	43.80	41.07
III	8	7,413	2,855	.39	1.37	14.15	85.08	.77	19.33	79.71	.96	8,683	1.17	2.66	46.69	59.57	71.80	55.94	42.78
IV	8	9,478	3,096	.33	1.44	10.14	89.67	.19	14.64	85.13	.23	9,800	1.03	3.41	41.49	78.02	77.36	69.51	60.36
V	8	9,820	10,301	1.05	1.72	7.27	92.34	.39	12.53	87.07	.40	10,175	1.04	2.66	48.54	80.68	39.11	61.10	31.56
VI	8	4,318	5,196	1.20	1.94	6.68	93.19	.13	12.94	86.91	.15	9,837	2.28	4.20	32.48	61.12	37.88	43.33	23.16
VII	8	5,847	5,266	.90	1.60	9.84	89.88	.28	15.77	84.05	.18	8,888	1.52	3.31	46.50	63.69	43.80	54.03	27.89
VIII	8	2,628	4,768	1.81	2.30	8.18	91.48	.34	18.84	80.82	.34	3,927	1.49	3.74	51.26	92.47	21.23	60.00	19.63
IX	8	3,145	3,080	.98	1.73	10.00	89.61	.39	17.31	82.35	.34	6,822	2.11	4.45	37.27	69.47	43.43	51.22	30.17
X	8	5,348	5,201	.97	1.82	9.55	89.68	.77	17.39	81.67	.94	4,702	.88	3.49	57.38	94.84	46.55	74.83	44.17
XI	4	2,489	4,549	1.83	2.00	16.73	82.26	1.01	33.39	65.86	.75	249	.10	1.32	91.79	99.05	8.43	92.40	8.36
XII	4	3,343	4,849	1.42	1.91	12.87	86.57	.56	24.59	75.02	.39	290	.09	1.27	91.09	99.63	24.08	93.15	23.99

SUMMARY OF RESULTS.

The principal points of interest in connection with the experimental spray work in the Grand Valley of Colorado may be briefly summarized as follows:

SEASON OF 1915.

The highest percentage of fruit free from worms obtained in the experimental plats in 1915 was 72.22, in a plat which received six applications of arsenate of lead paste, 2 pounds to 50 gallons. In the unsprayed plat there was but 13.51 per cent of worm-free fruit. Arsenate of lime, both homemade and commercial, gave poorer control than arsenate of lead. In the control of larvæ that attempt to enter the fruit by way of the calyx cavity the results indicate that a low-pressure fine mist spray is as effective as a high-pressure coarse spray. The number of stings per apple was considerably less in the unsprayed than in the sprayed fruit.

SEASON OF 1916.

The best result during the season of 1916, 89.7 per cent of the fruit free from worm infestation, was obtained in a plat sprayed four times with arsenate of lead powder, 1 pound to 50 gallons. In the unsprayed plat 30.98 per cent of the fruit was uninfested. The primary object of the season's work was to test a coarse spray applied by means of a short rod equipped with a Bordeaux nozzle in comparison with a fine spray applied with spray poles and whirlpool-disk type nozzles. The results indicate that better control was secured with the finer sprays applied with the spray poles.

SEASON OF 1917.

The highest percentage of fruit free from worms in 1917 was 78.06, as a result of six applications of arsenate of lead, 1 pound of the powder to 50 gallons of water, to which fish-oil soap was added at the rate of 2 pounds to 50 gallons. Two unsprayed plats yielded 8.83 and 8.54 per cent of fruit free from worms. Another plat sprayed with six applications of arsenate of lead, but without fish-oil soap, produced 62.10 per cent of worm-free fruit, thus indicating that the addition of a soap spreader was of some value. The results with the codling-moth trap did not indicate that it materially aided in the control of the codling moth during the time of the experiments. Nicotine sulphate gave poor control and in combination with arsenate of lead apparently had very little value in reducing worm infestation or sting injury. Arsenate of lime gave unsatisfactory results. The dust treatments were even more ineffective. The plat in which the calyx spray was omitted was heavily infested at the calyx end. Five spray applications produced practically as much good fruit as seven.

Season of 1918.

In 1918 in a plat sprayed six times with arsenate of lead and fish-oil soap at the usual strengths 77.36 per cent of the fruit was free from worms, this being the highest percentage of worm-free fruit obtained during the season. In two untreated plats, 8.43 and 24.08 per cent of fruit were free from worm infestation. The use of fish-oil soap in combination with arsenate of lead gave somewhat variable results. The codling-moth trap was of little value as a supplemental control measure. Arsenate of lead powder, one-half pound to 50 gallons, was about as effective as when used at twice this strength.

SUGGESTIONS FOR THE CONTROL OF THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO.

The experience of the writers and others who are acquainted with Grand Valley conditions indicates that the codling moth presents a very difficult problem. As previously stated, there are two full broods of larvæ per annum and a partial third brood. The moth is extremely prolific because of the warm dry climate, and, as a result, the apples are exposed to large numbers of newly hatching larvæ practically every day during the development of the fruit.

The primary object of spraying is to cover the fruit and foliage with poison, and when this is properly distributed good protection is obtained for a time. It is, however, quite impossible in commercial spraying to coat completely all parts of the fruit, and further, as the apple develops in size it gradually outgrows the spray residue. The result is, that with numerous larvæ seeking a place of entrance, some will start feeding where there is no poison, gain entrance, and thus produce wormy apples. It is not commercially profitable to spray too many times during the season, but a sufficient number of applications should be made at such intervals as constantly to provide a protective coating of poison on the fruit, particularly when the larvæ are hatching in large numbers.

As a result of the life-history investigations in the Grand Valley and other places, it has been found that the development of the codling moth from the time of hatching of the first eggs of the season does not as a rule vary to any great extent and that an average can be struck which, over a series of years, would usually represent the approximate development of the insect with sufficient accuracy for spraying purposes.

Some growers of the Grand Valley have attempted to ascertain the time to spray by making observations in the orchard, such as inspection of the leaves for eggs and of the fruit for newly entered larvæ. The writers are inclined to believe that this particular method as practiced by the fruit grower is unreliable and frequently misleading, although regular and systematic inspections over a considerable portion of the orchard will sometimes give information of value. As a rule, however, fruit growers have neither the time nor patience to undertake a careful orchard survey. On account of seasonal variations, calendar dates for making applications can not be depended upon, but a schedule based on certain intervals following the dropping of the blossom petals will usually result in timely spraying.

In formulating the control of the codling moth it is very important that the approximate time of the first hatching of each brood of larvæ and the relative number of worms that are developing from time to time be known. Complete and reliable data of this nature were obtained in the foregoing life-history studies, and with these data at hand it is believed that the most effective time for making the spray applications can be established.

The spray schedules that follow are based on the life-history studies of 1915 and 1916 and take into consideration the time when each brood begins to hatch, the time when the larvæ are hatching in large numbers, as well as the time when hatching occurs in maximum numbers. Three sets of schedules, I, II, and III, all starting from the time 90 per cent of the petals have dropped, are presented in Table 21, by reference to which it will be seen that schedule I calls for five applications and is intended for orchards having a relatively light infestation and for varieties on which the codling moth is not difficult to control; schedule II, six applications, for a medium infestation and for varieties on which the codling moth is moderately difficult to control; schedule III, seven applications, for a heavy infestation and for varieties on which the codling moth is most difficult to control.

The codling moth is normally abundant in the Grand Valley, and apples such as the Ben Davis, Schackelford, and other susceptible varieties will usually require schedule III, or seven treatments, especially if from previous neglect or other cause the infestation is very heavy; whereas, under similar conditions of infestation, varieties like the Winesap, on which the codling moth is more readily controlled, will require a smaller number of applications, as in schedules I or II. The degree of infestation varies somewhat from year to year and in the different fruit districts, and, as previously stated, the control of this insect varies with the different varieties. For these reasons, no one schedule will meet the demands of all the growers, and it will be necessary for each individual to forecast in advance what his conditions are likely to be and spray accordingly.

TABLE 21.—*Spraying schedules for the codling moth in the Grand Valley of Colorado.*

Application.	Spray application.	Time of application.	Applications.		
			I. Light infestation and with varieties on which the codling moth is not difficult to control.	II. Medium infestation and with varieties on which the codling moth is moderately difficult to control.	III. Heavy infestation and with varieties on which the codling moth is difficult to control.
Calyx spray	A.	Begin when 90 per cent petals have dropped and finish before calyces close.	First	First	First.
Cover spray, first brood.	B.	3 to 4 weeks after A, just previous to time when first-brood larvæ begin to hatch.	Second	Second	Second.
Do	C.	10 to 12 days after B, just previous to hatching of first-brood larvæ in large numbers.		Third	Third.
Do	D.	15 to 17 days after B, just previous to hatching of first-brood larvæ in maximum numbers.	Third		
Do	E.	10 to 12 days after C, for late hatching first-brood larvæ.		Fourth	Fourth.
Cover spray, second brood.	F.	9 to 10 weeks after A, just previous to time when second-brood larvæ begin to hatch.	Fourth	Fifth	Fifth.
Do	G.	24 to 26 days after F, just previous to hatching of second-brood larvæ in large numbers.			Sixth.
Cover spray, second and third broods.	H.	34 to 36 days after F, just previous to hatching of second-brood larvæ in maximum numbers and for protection against third-brood larvæ.	Fifth	Sixth	
Do	I.	15 to 17 days after G, for late hatching second-brood larvæ and for protection against third-brood larvæ.			Seventh.

From the foregoing schedules it will be seen that the first or calyx treatment is given in each schedule and that it should be started when about 90 per cent of the petals have dropped, and should be finished before the calyces close. The object of this application is merely to fill the calyx or blossom end of the fruit so that the worms that attempt to enter by way of the calyx will be killed by the poison lodged therein. Any spray applied after the calyx cups have closed will have no value in checking calyx worms. This application should be very thorough, and, for the sake of speed, it is advisable to use a spray under a pressure of about 225 pounds.

Schedule I consists of four cover sprays, the first of which should be applied three to four weeks after the calyx application, just previous to the time when the first-brood larvæ begin to hatch. This application will serve to coat the young fruit and foliage with poison as a protection against the early hatching worms. The second cover spray for the first brood should be applied 15 to 17 days later, just before the first-brood larvæ hatch in maximum numbers. The first cover spray for the second brood should be made 9 to 10 weeks after the calyx treatment, just prior to the time when the second-brood larvæ begin to hatch. The next and last application should be made 34 to 36 days later, in advance of the hatching of the second-brood larvæ in maximum numbers and for protection against the third-brood larvæ.

Schedule II is similar to schedule I except that five cover sprays are used instead of four, the additional application being made for the first-brood larvæ. The second cover spray should be applied 10 to 12 days after the previous treatment so as to cover the fruit just in advance of the hatching of the first-brood larvæ in large numbers. The next application should be made 10 to 12 days later as a means of protection against the late hatching first-brood larvæ.

Schedule III includes a total of seven applications, the first four being similar to those of schedule II. But in schedule III, three applications should be made for the second and third broods, the first of which should be applied 9 to 10 weeks after the calyx treatment, previous to the hatching of the second-brood larvæ. The next application should follow in 24 to 26 days, just before the hatching of the second-brood larvæ in large numbers and the last should be applied 15 to 17 days later, for late hatching second-brood larvæ and protection against worms of the third brood.

AVOID PRESENCE OF SPRAY RESIDUE ON HARVESTED FRUIT.

Orchardists understand the importance of and will naturally give attention to the carrying out of any spraying schedule in such a manner as to obviate as completely as possible the presence of spray residue on fruit prepared for the market. Such residue is objectionable to consumers, and while there is little chance of injury resulting from its use, there is no necessity under average conditions to spray to an extent that results in much spray on the fruit at harvest time. A heavy coat of spray residue at harvest time is frequently due to an attempt on the part of the grower to protect his nearly ripened fruit from an abundance of late hatching worms. This condition would not be so common or serious if the proper action and same amount of endeavor were directed against the elimination of the first-brood worms.

During certain seasons of unusual worminess or with particularly susceptible varieties, seven treatments may not always give the desired results, but it is believed that in most instances seven thorough, well-timed applications will give as good results as can be economically obtained in the Grand Valley.

The foregoing schedules are based on the general average life history of the codling moth in the Grand Valley under normal climatic conditions. But if there should occur any unusual departure from the normal, a corresponding variation in the development of the insect is to be expected, and the schedule of applications should be modified accordingly. Small deviations, however, should not cause the fruit grower to abandon his adopted schedule, since a matter of a few days one way or the other is not likely to affect the ultimate results to any marked extent.

Above all, the fruit grower should pay particular attention to spraying for the first-brood larvæ and make every effort to poison as many of these as possible. If all of the first-brood worms were killed there would be none of the second or third broods with which to contend. Upon inspection of their orchards early in the season, fruit growers sometimes conclude that there are so few worms present that it is unnecessary to make additional spray applications for the first brood. Unfortunately, it is not always realized that the presence of a comparatively few larvæ early in the season will often result in large second and third broods, which frequently will cause an enormous loss despite the most thorough subsequent spraying. The fruit grower should therefore bear in mind that during the early part of the season, while the fruit is small and the skin is not very waxy, it is easier to coat it thoroughly with poison and thus kill the worms than later in the year when the apples have grown larger and the skin has become smoother. Unless the fruit grower makes every effort to reduce to the minimum the number of first-brood larvæ, he will have small chance of success against the later broods. Neglect to spray with thoroughness and timeliness against the first brood of worms can never be economically or successfully overcome by sprays applied late in the season.

SPRAY MATERIALS.

Arsenate of lead at the rate of 1 pound of the powder or 2 pounds of the paste to 50 gallons of water is recommended as the most satisfactory poison for use against the codling moth. For convenience in handling and storing, the powdered product is preferable to the paste.

Although the experimental data did not always indicate that the addition of fish-oil soap to the arsenate of lead spray was of value, it is believed, nevertheless, that the use of soap, 2 pounds to 50 gallons, will generally increase the efficiency of the spray on account of the spreading qualities of the soap. Soap, however, should never be used with strongly alkaline water.

SPRAYING EQUIPMENT.

To spray the orchard as quickly as possible during the critical periods, it is recommended that a power sprayer of ample capacity and capable of supplying three leads of hose with a pressure of 225 to 250 pounds be used. In spraying large trees a spray tower, erected on top of the outfit, will enable the operator to cover the upper parts of the trees more thoroughly. A tank filler is almost a necessity and each sprayer should be provided with this device. It is also important to have well-made hose of sufficient length and hose couplings and clamps that will stand the strain of the work without breaking or allowing the hose to be forced off during the spraying operations.

As previously stated, it is believed that the use of spray poles equipped with the whirlpool-disk type of nozzles will result in a larger percentage of clean fruit than if the short rod and Bordeaux nozzle or the spray gun are used. The last two methods of spraying, however, will save considerable time and it is therefore a question of the value of time against a somewhat greater quantity of fruit free from worms. The choice of method will depend upon availability and cost of labor, weather conditions, size of orchard, and number of spray machines, severity of infestation, variety of fruit, and other factors. Under some circumstances the grower may find it an advantage to use the spray gun for the calyx application and the first cover spray, changing to the poles and finer sprays for the later treatments when the fruit is larger and the skin is smoother, more waxy, and more difficult to coat with the spray liquid.

SUPPLEMENTAL CONTROL MEASURES.

BANDING.

Despite the most thorough spraying some first brood larvæ will escape the poison, and after completing their feeding period within the fruit will leave it and spin their cocoons on the tree trunk and later develop into moths which will in turn produce second-brood larvæ. As a means of catching these larvæ the banding method may be practiced. This consists of scraping the trunk to remove the loose bark, thus destroying most of the places where the larvæ hide, and then placing around the trunk a burlap band, folded into two or three thicknesses to a width of about 6 inches. These bands should be examined every 10 days from about the middle of June to August 31, and all of the larvæ and pupæ found beneath should be killed. A final examination should be made any time after the fruit is harvested. The banding method, if properly worked from year to year in conjunction with thorough spraying, will gradually reduce the number of individuals in the orchard so that a larger percentage of worm-free fruit will be obtained than with spraying alone.

CODLING-MOTH TRAP.

A codling-moth trap has been devised as a substitute for the banding method. This device will serve the same purpose as banding and will obviate the necessity of working the bands during the growing season when labor is usually much needed for other duties. While the spraying experiments do not indicate any pronounced benefit through the use of the codling-moth trap, it should be borne in mind that this device was used only one season and then only in a part of each of the orchards; hence there was no chance to determine what cumulative effect it might have if used over a series of years and if applied to all of the trees in the orchard. Since we have no experimental data to indicate the cumulative value of the trap the writers are not in a position to make any recommendations, but for those who wish to give the trap a trial the following method of manufacture is suggested.

MANUFACTURE.

The materials needed for the manufacture of the codling-moth trap are as follows: Medium to heavy burlap, ordinary black-painted or japanned wire screen having 12 meshes to the inch, a folding machine such as that used by tinners to fold the edge of tin sheeting, and a crimping machine such as that used to reduce the end of stove pipe.

The burlap is cut into strips 6 inches wide and folded into three thicknesses by any convenient method. Wetting the burlap will make it fold more easily and remain better creased. To assist in this, however, it is well to roll the burlap up in flat rolls of any convenient size so that they can be easily handled in the field.

The wire screen is also cut into strips 6 inches wide and of any convenient length, depending on the length of the machine used to fold the edges. The edge of each strip should be folded at least once, preferably twice, using the folding machine mentioned above or any other convenient method. This fold should not be over three-eighths to one-half of an inch wide if folded once and not over one-fourth of an inch wide if folded twice. It is essential that the wire should be folded at least once and preferably twice, as the edges can then be crimped much better in the crimping machine and a more desirable bulge produced. Both edges of the strip are then run through the crimping machine, which should be set to make a fairly deep crimp without cutting the wire and about three-fourths to one inch from each edge. This crimp will aid greatly in giving, as stated above, a desirable bulge to the wire when it is applied to the tree, and further it will allow for the expansion of the tree trunk as it grows throughout the season. As the wire comes from the crimping machine it can well be rolled up into small rolls, which will greatly assist in keeping the crimp intact and also facilitate the manipulation of the wire in the field. If the crimping machine mentioned above can not be had, some other method, such as tucking the edges, must be adopted to give the desired bulge and to keep it away from the burlap on the tree.

APPLICATION.

The materials needed for the application of the codling-moth trap to the tree are as follows: A supply each of burlap and wire screen prepared as described above, a supply of slate nails about an inch or more long, 10-ounce bill-posting tacks, tinner shears, a claw hammer, tar such as that used for roofing purposes (sometimes called "pitch tar"), a melting pot or a small pail conveniently arranged over a flame, and a small dauber.

The strip of folded burlap is then placed completely about the trunk of the tree to be trapped. It may be placed at any convenient height between the lowest limb and the ground, and an overlapping of an inch or two should be left to allow for the expansion of the tree. The loose bark should be scraped from the trunk, lower branches, and the crotches of each tree on which the codling-moth trap is applied in order to destroy as many places as possible where the codling-moth larva might spin its cocoon and there transform to the adult or moth stage. The burlap should be held in place by slate nails about an inch in length driven in at several points around the tree trunk so that the head projects not less than half an inch beyond the burlap, preferably three-fourths of an inch. This is essential in order to hold the wire safely away from the burlap at such a distance as will prevent the pupæ, just before the moths emerge, from wriggling up to or through the meshes of the wire and the moths from emerging on the outside of the trap.

With the burlap in place and the slate nails in their proper position, the wire screen, as prepared above, is ready to be tacked into place. Start at any convenient point and in any convenient direction around the tree by putting one tack in the corner on the lower edge of one end of the wire-screen strip, holding the strip so that the burlap band will be in the middle. Then place a tack in the corner on the upper edge, shoving down on this edge slightly, so as to spring the wire away about 1½ inches or more from the tree at this point. Proceed around the tree trunk with the wire, holding it so that the burlap will be in the center all the way around and placing just enough of the 10-ounce bill-posting tacks along the edges of the wire to hold it snugly to the tree at all points, particularly where there are slight depressions or hollows which can not be sealed over with the tar, as outlined below.

Here care should be taken not to stretch the wire while it is being tacked to the tree, as this will pull out the crimp and make the formation of a desirable bulge rather difficult. Care should also be taken while the wire is being tacked into place to push the two edges together somewhat in order to increase the bulge already made by the crimping. This bulge should be large enough so that the middle of the strip will be approximately 1 inch from the burlap at every point. It is entirely possible to produce a bulge of over 2 inches, provided the wire is properly crimped and the edges are pushed together in the proper fashion. A little practice, however, will develop considerable skill along this line. An overlapping of several inches should be left when the wire has been completely fastened around the trunk of the tree, and this overlapping should be stretched slightly over the wire beneath, so as to make a tight joint. If, as pointed out above, care is taken to produce a bulge sufficient to hold the wire well away from the burlap, to fit the wire snugly to the tree and make the overlapping tight, the codling-moth trap will remain in perfect operation throughout the season. It will then be practically impossible for the pupæ, just before the moths emerge, to work their way up to the wire, allowing the moths to emerge on the outside of the trap, a thing which is sure to happen when the wire is close to the burlap.

Care should be taken that there are no openings between the wire and the tree trunk through which moths may escape from the trap. These can be prevented by placing a thin coating of ordinary roof tar over the edges of the trap. This is a very practical and convenient method of making traps moth-tight. The tar can be conveniently melted in a small melting pot or pail held over a flame and can be applied best by means of a small stick with a bit of cloth on the end. Tar can not be applied easily with a brush. In applying the tar, roll the stick or the dauber toward the tree as it is passed along the edges of the trap. The tar need not be applied until shortly before the time the first moth of the first brood emerges.

MAINTENANCE.

When once attached to the tree as outlined above and carefully sealed with tar, the codling-moth trap should remain in perfect operation throughout the season and should require very little attention. In some cases an inspection the following spring to close up any holes which may have formed will be sufficient to put the trap in condition for another year.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
△